

SUCCESSFUL SPACE FLIGHT OF HIGH-SPEED InGaAs PHOTODIODE ON-BOARD THE INTERNATIONAL SPACE STATION

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Introduction

Photonic systems are required for several space applications, including satellite communication links and lidar sensors. Although such systems are ubiquitous in terrestrial applications, deployment in space requires the constituent components to withstand extreme environmental conditions, including wide operating temperature range, mechanical shock and vibration, and radiation. These conditions are significantly more stringent than alternative standards, namely Bellcore GR-468 and MIL-STD 883, which may be satisfied by typical, commercially available, photonic components. Furthermore, it is very difficult to simultaneously reproduce several aspects of space environment, including exposure to galactic cosmic rays (GCR), in a laboratory. Therefore, it is necessary to operate key photonic components in space to achieve a technology readiness level of 7 and beyond. Accordingly, the International Space Station (ISS) provides an invaluable test bed for qualifying such components for space missions.

We present a fiber-pigtailed photodiode module, having a -3 dB bandwidth of 16.8 GHz, that survived 18 months on the ISS as part of the Materials International Space Station Experiment (MISSE) 7 mission [1]. This module was launched by NASA Langley Research Center on November 16, 2009 on the Space Shuttle Atlantis (STS-129), as part of their lidar transceiver components. While orbiting on the ISS in a passive experiment container, the photodiode module was exposed to extreme temperature cycling from -157 °C to +121 °C 16 times a day, proton radiation from the inner Van Allen belt at the South Atlantic Anomaly, and galactic cosmic rays [2, 3]. The module returned to Earth on the Space Shuttle Endeavor (STS-134) on June 1, 2011 for further characterization. The post flight test of the photodiode module, shown in Fig. 1a, demonstrates no change in the module's performance, thus proving its survivability during launch and in space environment.

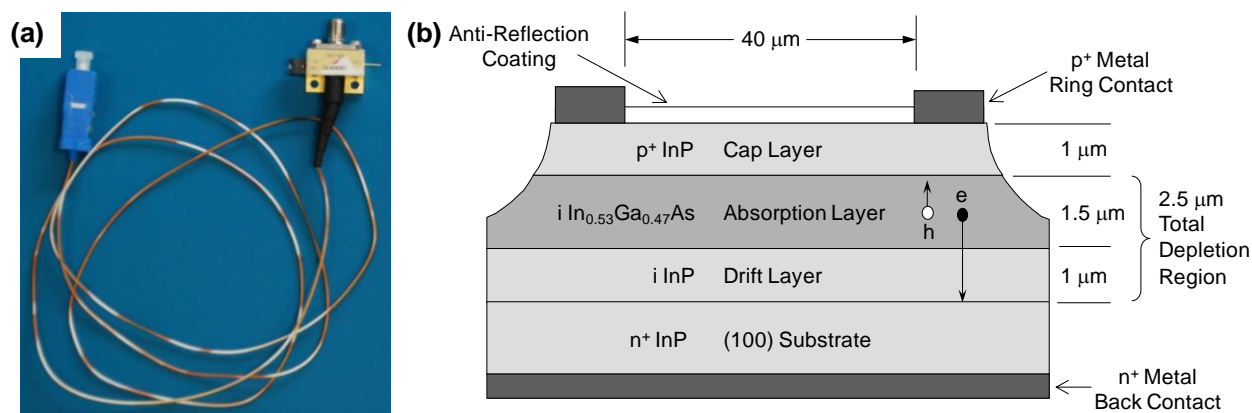


Figure 1. (a) Photograph of fiber-pigtailed InGaAs photodiode module returned to Earth after 18 months on the International Space Station (ISS) as part of MISSE 7 mission. (b) Ultra-fast Dual-depletion InGaAs photodiode structure with proven rad-hard design.

Device Description

The top-illuminated InP/InGaAs photodiodes used for this work employ the dual-depletion region (DDR) photodiode structure, shown in Fig. 1b, which has a proven track record for ultra-fast operation and high linearity. The inclusion of the high bandgap InP Drift Layer in the photodiode's depletion region has an

additional advantage of making it rad-hard by design. The photodiode module contains a 40 μm diameter device, which was terminated with a 50 Ω resistor and coupled to a 9 μm core, standard single mode fiber in a compact 3-pin microwave package. Similar modules have previously passed several space qualification tests, including 33 g of mechanical vibration, 58.6 krad of 35 MeV proton radiation, and 50 krad of 1 MeV gamma radiation, and have been incorporated into the lidar instruments of the European Space Agency's AEOLUS and ATLID missions [4].

Results

After returning from the ISS, the photodiode module exhibited a coupled DC responsivity of 0.81 A/W at 1550 nm wavelength, dark current of 4.3 nA at 5 V reverse bias and 23 $^{\circ}\text{C}$ (see Fig. 2a), and -3 dB bandwidth of 16.8 GHz (see Fig. 2b). These performance metrics were identical to pre-flight results. This consistency not only validates the DDR photodiode structure, but also the integrity of the opto-mechanical assembly of the photodiode module.

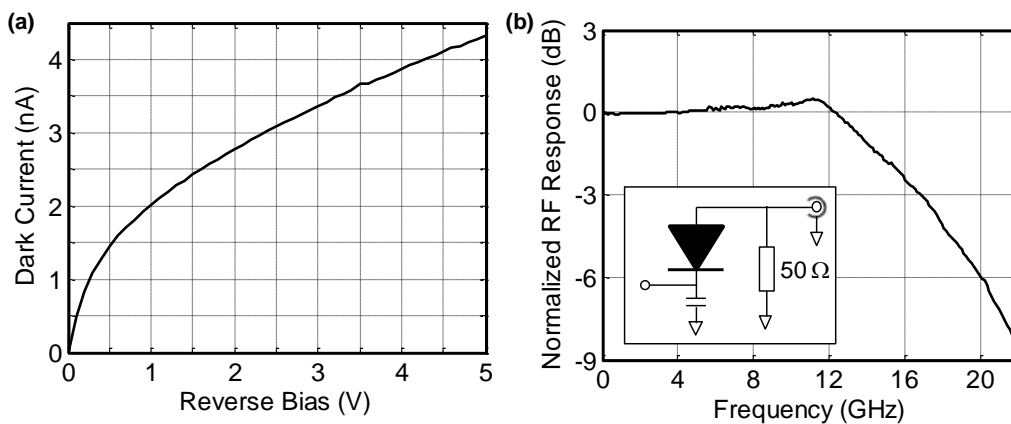


Figure 2. (a) Dark current at 23 $^{\circ}\text{C}$ temperature and (b) RF response at 5 V reverse bias of the InGaAs photodiode module after returning from the ISS. (Inset) Equivalent circuit of the InGaAs photodiode module with internal resistive 50 Ω resistive termination.

Conclusions

We have demonstrated a 16.8 GHz photodiode module that has survived 18 months on the ISS as part of the Materials International Space Station Experiment (MISSE) 7 mission without any change in device performance. This module was subjected to launch vibrations, as well as harsh space environment, namely temperature cycling from -157 $^{\circ}\text{C}$ to +121 $^{\circ}\text{C}$ 16 times a day, proton radiation from the inner Van Allen belt at the South Atlantic Anomaly, and GCR. This experiment serves as a pathway for increasing the TRL level of these photodiodes to 7, thus, getting them space qualified for several NASA missions.

References

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